Implementation of the Personal Emergency Response System

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***Abstract*—**The aged are faced with increasing risk for falls. The aged have the easily fragile bones than others. When falls have occurred, it is important to detect this emergency state because such events often lead to more serious illness or even death. A implementation of PDA system, for detection of emergency situation, was developed using 3-axis accelerometer in this paper as follows. The signals were acquired from the 3-axis accelerometer, and then transmitted to the PDA through Bluetooth module. This system can classify the human activity, and also detect the emergency state like falls. When the fall occurs, the system generates the alarm on the PDA. If a subject does not respond to the alarm, the system determines whether the current situation is an emergency state or not, and then sends some information to the emergency center in the case of urgent situation. Three different studies were conducted on 12 experimental subjects, with results indicating a good accuracy. The first study was performed to detect the posture change of human daily activity. The second study was performed to detect the correct direction of fall. The third study was conducted to check the classification of the daily physical activity. Each test was lasted at least 1 min. in third study. The output of acceleration signal was compared and evaluated by changing a various posture after attaching a 3-axis accelerometer module on the chest. The newly developed system has some important features such as portability, convenience and low cost. One of the main advantages of this system is that it is available at home healthcare environment. Another important feature lies in low cost to manufacture device. The implemented system can detect the fall accurately, so will be widely used in emergency situation.

Manuscript received July 31, 2007. This work was supported by a grant of the Korea Health 21 R&D Project, Ministry of Health & Welfare, Republic of Korea(Grant No: A040032).

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***Keywords*—** Alarm System, Ambulatory monitoring, Emergency detection, Classification of activity, and 3-axis accelerometer.

I. INTRODUCTION

AS the birth rate has decreased, whereas the average span of life has increased. People who are aged at 65 or older are the fastest growing population of the world. So, we are currently faced with a wide range of problems which are related to the ageing society, emerging needs of home-visit nursing and ubiquitous healthcare. Especially, the aged are at an increasing risk for falls. When a falls has occurred, it is important to detect the situation accurately because such accidents often lead to more serious illness or even death. The early detection of emergency like falls is essential to rescues the injured from danger and ask for a aid as fast as possible.

So, the monitoring and classifying the human movement is important. In the past, the ambulatory measurement of the physical activity was based on various motion sensors such as pedometers and actometers. Recently the accelerometer has been employed to facilitate such long-term monitoring of human motion by using the wearable sensor unit [1], [2]. And, many of systems utilized the multiple accelerometer units which are placed at various sites of the body to assist their detection of activities such as walking, ascending and descending stairs, and cycling [3]-[5]. And, in another research, a kinetic sensor, which is composed of one miniature piezoelectric gyroscope and two miniature accelerometers, was used to analyze the human motion [6], [7]. Furthermore, new systems were developed to identify the static and dynamic activity using 3-axis accelerometer [8], [9]. However, these methods are somewhat cumbersome because they needed two or more different sites of sensor attachment to the body and cable connection, which is reducing their applicability for long-term monitoring physical activity and interfering activities.

The PDA system was developed in this research using 3-axis accelerometer, which could classify the human activity and detect the emergency state, more conveniently. This system can easily detect the posture change, fall, and daily physical activity. The system can generate the alarm on the PDA (Acode-300, Chipsen, Co. Korea), when urgent situation like the fall is detected. If the subjects do not respond to the alarm, the system will determines that the current situation is an emergency state, and then informs the emergency center.

II. Methods

A. Instrumentation

The proposed system can acquire the x-axis (left (+) – right (-)), y-axis (up (+) – down (-)), z-axis (rear (+) – front (-)) signals from the 3-axis accelerator (MMA 7260Q Free scale Co. USA), monitor the signals via PDA, and detect an emergency state like falls.

Fig. 1 shows the schematic diagram of the PDA system for detecting an emergency state. The different 3-axis signals were generated as a motion of the subject in a specific situation such as walking, lying, and so on. The whole block diagram of the system was shown in Fig. 2.

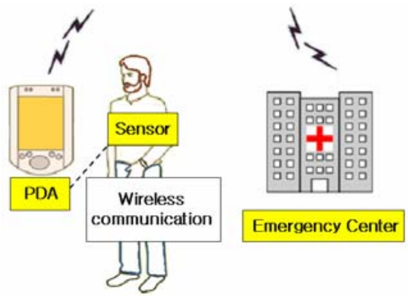

Fig. 1 Schematic of PD system for detecting emergency state

The output signal (X, Y, Z) of 3-axis accelerometer was transmit to three channel of DAQ board. And these signals transmit to PDA via Bluetooth module. The acquired signals were analyzed via LabVIEW software (LabVIEW 7.1.1, N.I. Co., U. S. A.).

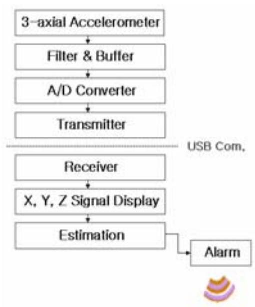

Fig. 2 Block diagram of the system

B. Experimental Protocol

The signals were acquired using the 3-axial accelerometer, which was attached on the chest of the subject, to detect signals according with the posture change. The experimental protocols of the posture change and fall, and daily physical activity are represented by respectively in Table I, II, III.

Three different studies which are posture change, fall, daily physical activity, were conducted on the 12 experimental subjects. The first study was conducted to check the correct analysis of the posture change. The experimentation protocol of posture change was represented Table I.

TABLE I
Experiment 1: Description of Activities Performed by Each Subject to Analyze Human Activity

Task	Description	Duration (s)
Sit-to-stand	From an initially seated position, the subject stands up and remains standing	10
Stand-to-sit	From an initially stranding position, the subject sits down and remains seated	10
Sit-to-lying	Initially sitting up on the mattress, the subject lies down on their back and remains in this position	10
Lying-to-sit	Initially lying on the their back on the mattress, the subject sits up and remains in this position	10
Stand-to-walking	From an initially standing position, the subject walks and remains in this position.	10
Lying (back-right-back -left-back)	From an initially lying backward (5 s), rightward (5s), backward (5s), leftward (5s), and backward	25

The second study was conducted to check the correct detection of fall according to the direction. The subjects performed 4 different tests including frontal fall, back fall, left fall, and right fall as described in Table II.

TABLE II
Experiment 2: Description of Activities Performed by Each Subject to Detect Fall

Task	Description	Duration (s)
Frontal fall	Initially standing up, the subject falls frontward onto the mattress	10
Back fall	Initially standing up, the subject falls backward onto the mattress	10
Left fall	Initially standing up, the subject falls leftward onto the mattress	10
Right fall	Initially standing up, the subject falls rightward onto the mattress	10

The third study was conducted to check the classification of the daily physical activity. Each test was lasted at least 1 min. respectively task in this experiment. Activities performed by subjects were described in Table III.

TABLE III
Experiment 3: Description of Activities Performed by Each Subject to Classify the Daily Physical Activity

Task	Description	Duration (s)
Stand-walking-stand-sit-lying-sit-stand	Initially standing up, the subject is walking, standing, sitting, lying, sitting and standing.	10
Stand-walking-stand-sit-lying-sit-stand-fall	Initially standing up, the subject is walking, standing, sitting, lying, sitting, standing, and falling forward onto the mattress	10

C. Algorithm of Classifying the Human Activity

To distinguish of the experimental subject's activity, that is posture change, fall, and daily physical activity, the classifying algorithm of the human activity was used in this study.

A suitable parameter for detection of the subject's behavior aspect, discussed in previous studies [1] is normalized Signal Magnitude Area (SMA).

$$SMA = \frac{1}{t}\left(\int_0^t |x(t)|\,dt + \int_0^t |y(t)|\,dt + \int_0^t |x(t)|\,dt\right) \quad (1)$$

The SMA defined in equation (1) is used as basis for identifying the subject's behavior aspect, which is running, fast walking, sitting, standing, and lying.

Where x(t), y(t), and z(t) refer to the acquired sample signals according to posture change from the x, y, and z-axis accelerometer, respectively. Calculation of this parameter is performed by summing each samples value progressively over 1 second interval. An appropriate threshold value was determined via testing-for an SMA value, in which activity was deemed to have occurred, and values below the threshold is considered in the resting state.

D. Algorithm of Detecting the Fall

Falls have occurred if at least two consecutive peaks in the signal magnitude vector (SVM) above a defined threshold are recorded.

$$SVM = \sqrt{x_i^{\,2} + y_i^{\,2} + z_i^{\,2}} \quad (2)$$

SVM, defined in equation (2), essentially provides a measurement of the degree of movement intensity, as derived from the TA (output of the 3-axis accelerometer) output signal. The fall detection technique and the associated threshold are described in refer to other research [1]. The threshold was determined by considering accelerations in SVM and in x, y, and z-axis, whereas falls and stumbles were simulated. A review of these test results has been identified the most suitable parameter to be SVM at a threshold of 1.8 g. The system generates the alarm on the PDA, when the fall is detected. If a subject does not respond to the alarm, the system determines whether the current situation is an emergency state or not, and sends some information to the emergency center in the case of an emergency as shown in Fig. 3.

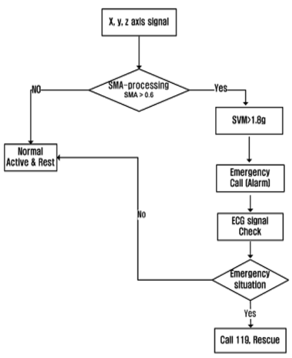

Fig. 3 Algorithm of detecting the falls

III. Results

The experimental subjects performed a various tests using 3-axis accelerometer attached on the chest. Fig. 6 shows the variation aspect of the acquired 3-asix accelerometer signals and SMA and SVM parameters according to the variation of walking speed, that is, slow walking (S.W), normal walking (N.W), fast walking (F.W), and fall down forward (F). Acquired data from each axis was normalized, with the assumption that z-axis is always under the gravitational acceleration 1g as the standard of signal magnitude.

As shown in the Fig. 4, the z-axis signal was indicated more closely related to the walking than x-axis and y-axis signal. The 3-axis signal, SMA and SVM increased according to the increase of the walking speed. And, the activity state could not be determined by analyzing the SMA and SVM.

Because the direction of fall down is front, the amplitude of x-axis and z-axis signal was observed considerably high more than the experimental subject fall down. And SMA and SVM were observed also very high, in this case, than the walking state.

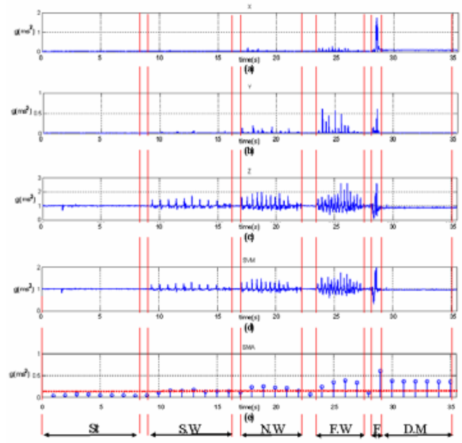

Fig. 4 Variation aspect of 3-axis accelerometer signal and SMA and SVM parameters after normalized process according to walking speed change and fall down: (a) x-axis signal, (b) y-axis signal, (c) z-axis signal, (d)SVM and (e)SMA

The mean and standard deviation of SMA and SVM according to the variation of walking speed and fall was shown in Table IV.

TABLE IV
The Mean and Standard Deviation of SMA and SVM according to Walking Speed Change

Pattern		SMA (g)		SVM (g)	
		Mean	SD.	Mean	SD.
Slow walking	Woman	0.15	0.05	1.15	0.05
	Man	0.19	0.03	1.21	0.08
Normal walking	Woman	0.21	0.06	1.25	0.12
	Man	0.23	0.04	1.42	0.10
Fast walking	Woman	0.35	0.05	1.60	0.21
	Man	0.37	0.04	1.92	0.19
Running	Woman	0.51	0.05	2.05	0.26
	Man	0.56	0.06	2.14	0.21
Fall	Woman	0.60	0.10	2.31	0.26
	Man	0.65	0.15	2.65	0.31

The classified by of activity pattern were not identified using the value of SMA and SVM in Table IV. But, SMA and SVM were distinguished, when the experiment subjects fell down. The value of SMA is approximately 0.6, and the value of SVM is approximately 2.31 ~ 2.61.

The accuracy of correctly classifying the activity in this the system was shown in the Table V. Experiment I and II is conducted three times on each subject, and Experiment III is conducted two times on each subject.

TABLE V
THE MEAN AND STANDARD DEVIATION OF SMA AND SVM ACCORDING TO WALKING SPEED CHANGE

Experiment	Task	Total Test	Overall Correct	Overall Incorrect	Accuracy (%)
I	Sit-to-stand	36	34	2	94.44
	Stand-to-sit	36	35	1	97.22
	Sit-to-lying	36	36	0	100
	Lying-to-sit	36	36	0	100
	Stand-to-walking	36	35	1	97.22
	Lying(back-right-back-left-back)	36	29	7	80.55
II	Frontal fall	36	36	0	100
	Back fall	36	36	0	100
	Left fall	36	32	4	88.88
	Right fall	36	35	1	97.22
III	Stand-walking-stand-sit-lying-sit-stand	24	21	3	87.5
	Stand-walking-stand-sit-lying-sit-stand-fall	24	23	1	95.83

Viewing the results as a whole, the accuracy of experiment I to analysis activity was 94.9%, 96.52% on the experiment II to detect falls, 91.665% on experiment III to classify the daily physical activity.

As above, the accuracy of left fall was 88.88 % on experiment II to detect the fall. The reason of this is supposed that the whole subjects are right handed, so they're conscious of the experiment. Even though there was some error, overall result of study was considerably reliable.

IV. DISCUSSION AND CONCLUSION

The PDA system was developed using the 3-axis accelerometer. This system could classify the human activity, and also detect the emergency like a fall. The system generates the alarm on the PDA, when the fall is detected. If a subject does not respond to the alarm, the system determines whether the current situation is an emergency state or not, and then sends some information to the emergency center in the case of emergency.

This system has some important features such as portability, convenience and low cost which the previous systems didn't meet. However, one of the main advantages of this system is that it is available at home visit nursing and home healthcare environment. Most of the previous devices are check the wearer's conditions indoors. Even though there are a few outdoor devices, they are not only cost efficient but also utility efficient. It is certainly true that sometimes, many of the previous devices are inconvenient and complex to handle. Also it is possible not to deal with emergency situation properly.

The device developed in this work is so small that it is easy to carry when the wearers go anywhere. The wearer just wears the device on the chest. When the wearer suddenly fall down due to any situation like slippery roads and disease, the device can detect and help quick medical treatment through sending some information to emergency center. It can provide the prompt service for people in emergency situation. It is especially beneficial when the wearer such as the aged fall down where no one is around him or her. As soon as emergency center gets the information from the PDA, the center can identify where the aged fell down through signals of the device. The center can call ambulance and send people who can provide a help. It is certain that this device is very useful when the accident like a fall occur.

Another important feature of our device is that it is very simple. In fact, the business for the aged is expected to grow substantially. Therefore, many devices for the aged to cope with emergency state have been invented in recently years. Many of them introduce high IT and BT technology. It needs high cost, so people who can use the devices are limited. But, the newly developed system is suppose to overcome these drawbacks, and adopted the useful algorithm of detecting emergency state like falls.

Moreover the result of the test was considerably reliable. The developed system in this work can detect the fall well, so can be widely used in ubiquitous health care and emergency monitoring.

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